Engineering Mathematics Obstacles and Improvement: A Comparative study of Students and Lecturers Approaches through Creative Problem Solving

Hamidreza Kashefi[a], Zaleha Ismail [a], Yudariah Mohammad Yusof[b]

[a]Department of Science and Mathematics Education, Faculty of Education,
Universiti Technologi Malaysia (UTM), 81310 Johor, Malaysia
khamidreza4@ siswa.utm.my, zaleha@mathed.utm.my
[b]Department of Mathematics, Faculty of Science,
Universiti Technologi Malaysia (UTM), 81310 Johor, Malaysia
yudariah@mel.fs.utm.my

Abstract

Research findings indicate that for most engineering students, mathematics has always been one of the most difficult courses to study. Some researchers at Universiti Teknologi Malaysia (UTM) try to support students to overcome their obstacles in Engineering Mathematics by promoting mathematical thinking. This study is part of a project concerned with the students' obstacles in face-to-face Engineering Mathematics classrooms through this approach. The main data collection for this study was carried out through students' structured questionnaires of three classes at UTM in the end of semester. The findings showed that the students' obstacles from students' and lecturers' approaches are approximately the same and the majority of each group separately believed that two main obstacles in the learning of Engineering Mathematics are imaging and sketching in the 3-dimensions. The analysis showed that for both groups different thinking skills and tools from Creative Problem Solving are less important methods that can help students to overcome learning obstacles. This paper will propose some reform in the engineering curriculum to improve students' and lecturers' views on the way mathematics should be taught and learned.

Keywords: Engineering Mathematics; Creative Problem Solving; Mathematical Thinking; Students' Obstacles.

1. Introduction

Mathematics is a prime constituent and infrastructure of the education of engineering students. The main goal of mathematics learning for engineering students is the ability of applying a wide range of mathematical techniques and skills in their engineering classes and later in their professional work (Craft & Ward, 2001). Calculus as an important course for engineering students, provide them to work with several mathematical ideas and various representations and also use this knowledge in their engineering fields (Roselainy, Sabariah & Yudariah, 2007).

However, for many engineering students calculus is one of the most difficult courses in their field of study. Many students will struggle as they encounter the non-routine problems in calculus that are not solved by routine methods of problem solving. Some students' obstacles for teaching and learning of basic calculus in undergraduate mathematics are (Tall & Schwarzenberger, 1978; Tall, 1985, 1988, 1993):

- the particular events in past experiences of students,
- the mathematics concepts which carry complex meaning ,
- the way of transferring of mathematics:
  - using the ambiguities of language,
  - the appropriate learning sequence-studying simple ideas for so long way,
  - translating real-world problems into calculus formulation,
- restricting mental images of some concepts,
- selecting and using appropriate representations,
- confusing in the specific concepts,
- poring ability in algebraic manipulation – or lack of it,
- absorbing complex new ideas in a limited time,
- focusing on procedural and routine methods rather than conceptual understanding,
- poor problem solving skills,
- students' believes and learning styles.

Basic calculus is an important course for engineering students that is offered as pre-requisite course to other advanced mathematics courses. The lack of understanding of concepts in basic calculus may hinder the understanding of other concepts or even subjects. In this sense, basic calculus like analysis is a "pop up" subject, in that if a difficulty is smoothed over in one places it will pop up somewhere else (Schwarzenberger, 1980; Tall, 1992). Studies done by Yudariah & Roselainy (2004), Roselainy, Sabariah & Yudariah, (2007), and Sabariah, Yudariah & Roselainy (2008) on students' learning difficulties and also teaching challenges in multivariable calculus (Engineering Mathematics) classroom indicate that understanding basic calculus as a pre-requisite play an important role for understanding of Engineering Mathematics. According to their findings some students' obstacles in the learning of Engineering Mathematics are from basic calculus and some of them are new. Some teaching challenges in Engineering Mathematics classroom based on their study are:

- no priority of mathematics for engineering students,
- wide range of mathematical abilities and different levels of mastery of prior knowledge including:
  - algebraic skills (manipulating symbols in flexible way),
  - understanding basic skills,
  - recalling of knowledge fact,
  - the quite entrenching of students in their learning behavior and styles,
- coordinating multiple procedures,
- answering non-routine questions.

There are many methods for supporting students' learning to overcome their obstacles in mathematics. Creative Problem Solving (CPS) as a framework for solving problems in engineering, science, and mathematics courses employs different thinking skills and tools and fundamentally improves the ways of students' learning in these subjects especially in engineering mathematics (Lumsdaine & Voitle, 1993b). The roots of CPS are found in Osborn's works (1953, 1963) and it followed by many researchers like Parnes (1967), Isaksen & Treffinger (1985), Isaksen, Treffinger & Dorval (1994). Lumsdaine & Lumsdaine (1995) state the CPS as five distinct steps: (i) Problem Definition, (ii) Idea Generation, (iii) Creative Idea Evaluation, (iv) Idea Judgment, (v) Solution Implementation and show the relations between these stages and the four-quadrant thinking of brain in Herrmann Model (1988, 2001). They believe that the process of CPS involves all analytical, creative, critical, and visual thinking and it can be used to strengthen the quality of teamwork, thinking and communication skills of students in whole brain (Lumsdaine & Lumsdaine, 1995).

Using CPS not only can help students in Engineering Mathematics learning but also can support students' generic skills such as communication and team work as two important weaknesses of engineering students after graduation in their work place (Lumsdaine & Voitle, 1993a; León de la Barra et al., 1997). Comparing with engineering and science subjects there are very little researches in using CPS in mathematics; however, some researchers use some strategies to support students' learning by invoking other thinking and generic skills.

In the study of Engineering Mathematics, Roselainy and her colleagues (Roselainy, Yudariah & Mason, 2007; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008) presented a model of active learning that is based on invoking students' mathematical thinking powers, supporting mathematical knowledge construction, and promoting generic and soft skills that students need to know as an engineer. They had used themes and mathematical processes through especially designed prompts and questions to invoke and support students' use of their own mathematical thinking powers during face-to-face interactions in classroom setting. They employed different thinking skills and strategies in their method like CPS (instead of visual thinking); however, their method is more based on mathematical thinking approach.

In this study, we explain how this method tries to overcome students' obstacles in Engineering Mathematics by promoting mathematical thinking. Furthermore, we identify the students' obstacles in the learning of Engineering Mathematics through this method and the ways for improving them from students' approaches as an important goal of this study. Then, we compare lecturers' approach about students' obstacles and the ways for helping them in the learning of Engineering Mathematics from with students approach. Finally, we identify and compare how much employing different thinking skills and tools from CPS are important to support students in their obstacles from students and lecturers views.

2. Engineering Mathematics through Mathematical Thinking Approach

In the earlier study (Yudariah & Roselainy, 2004; Yudariah, Roselainy & Mason, 2007; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008), in developing the mathematical pedagogy for classroom practice, they adopted the theoretical foundation of Tall (1995) and Gray et al. (1999) and used framework from Mason, Burton & Stacey (1982) and Watson & Mason (1998). They focused on three major aspects of teaching and learning: the development of mathematical knowledge

construction, mathematical thinking processes, and generic skills)Fig. 1). They highlighted some strategies that can help students to empower themselves with their own mathematical thinking powers and help them in construction new mathematical knowledge and soft skills, particularly, communication, team work, and self-directed learning. Furthermore, the mathematical thinking activities can be taught of as powers were: specializing and generalizing, imagining and expressing, conjecturing and convincing, organizing and characterizing (Yudariah & Roselainy, 2004; Roselainy, Sabariah & Yudariah, 2007).

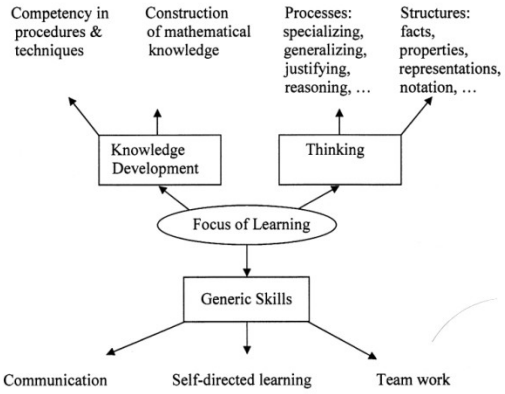

Fig. 1. Focus of mathematical learning.

Roselainy, Sabariah & Yudariah (2007) had developed and implemented their model of active learning in the teaching of Engineering Mathematics at UTM. They considered the following aspects in the implementation of active learning in Engineering Mathematics classroom (Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

- classroom tasks- by categorizing book as *Illustrations*, *Structured Examples* and *Reflection* with *Prompts and Questions*.
- classroom activities (approaches)- by working in pairs, small group, quick feedback, students' own examples, assignments, discuss and share, reading and writing.
- encouraging communication- by designing prompts and questions to initiate mathematical communication.
- supporting self-directed learning- by creating structured questions to strengthen the students' understanding of mathematical concepts and techniques.
- identifying types of assessment- by incorporating both summative and formative types.

Fig. 2 gives a summary of their model for active learning (Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

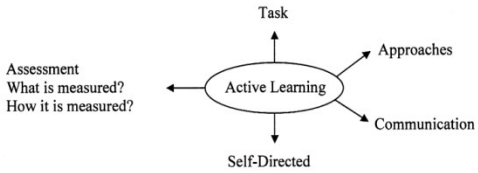

Fig. 2. Model of active learning.

In other words, they had provided and promoted a learning environment where the mathematical powers are used specifically and explicitly, towards supporting students (i) to become more aware of the mathematics structures being learned, (ii) to recognize and use their mathematical thinking powers, and (iii) to modify their mathematical learning behavior (Yudariah & Roselainy, 2004; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

3. Method

This study is part of a project concerned with the students' obstacles in face-to-face Engineering Mathematics classroom through Roselainy and her colleagues' method at UTM in the semester I 2009-2010. The Engineering Mathematics is offered at UTM as three credits for first-year undergraduate engineering students. The pre-requisite for this course is basic calculus and it focused on consisting of the following topics: functions of several variables, partial derivatives, multiple integrals, vector functions, and vector calculus. These topics are covered within 14 weeks with 3 hours of lectures and one hour of tutorial per week (Yudariah & Roselainy, 2004). The *Engineering Mathematics for Independent Learners* by Yudariah, Sabariah & Roselainy (2009) was the name of their book that was written as textbook based on their method. This book consists of five chapters that cover all topics in Engineering Mathematics course.

The sample of this study consisted 178 first year undergraduates' students in three Engineering Mathematics classes of Faculty of Electrical Engineering at UTM that are taught by Roselainy and her colleagues' method. Furthermore, to find the lecturers approach about students' obstacles and the ways of improving them we selected 10 lecturers from Department of Mathematics of Faculty of Science at UTM that they were teaching Engineering Mathematics.

The main data analyzed for this research were taken from students' structured questionnaires (distributed in the end of the course) about their obstacles in Engineering Mathematics course and the ways of improving them based on their view. The students' structured questionnaire was included two open ended questions (Question 1 & 3) and a ranking question (Question 1) as the following.

1. What are the greatest difficulties facing you in Engineering Mathematics so on?
2. How would you rank the following methods (Table 1) to help your learning in Engineering Mathematics? (1 for the most important …13 for the least important)

Table1. The methods of improving students' obstacles

Method	Average ranking
Choosing relevant topics	
Choosing problem related to the real world or students' major	
Simplified concept	
Teaching at students' level (peer teaching)	
Lecturer encouragement	
Individual homework and assignment	
Group project	
Quiz/ test/ assessment or exam	
Group work (collaboration) in the class	
Classroom discussion with the peers and lecturer	
Peer and lecturer online /offline supports in the outside of class (Chat/ email/ online bulletin board …)	
Using computer facilities (software / simulations/ calculator …)	
Using online facilities (website/ web learning modules/ online self assessment/ library…)	

3. Do you have any suggestion to help your learning in Engineering Mathematics except above-noted methods?

Furthermore, the students' structured questionnaires with a little change was administered and collected independently of Engineering Mathematics lecturers (distributed in the end of the semester). Not only did this allow the students' obstacles to be compared directly with those expected by the lecturers, it also allowed us to compare the students' suggestions to improve these difficulties with the methods which lectures preferred.

4. Discussion

4.1. Student's Questionnaires Results

The imaging and sketching in 3- dimensions were the greatest difficulties for majority of students in the learning of Engineering Mathematics based on common students' respond to this question: "what the greatest difficulties are facing students in Engineering Mathematics." In this method, the student' imaging and sketching were supported by illustrating the graphs during the lectures through using the overhead and the textbook that it seems could not enough support visual thinking like computer facilities. Furthermore, most students mentioned that too much concepts/ facts/ theorems/ formulas, memorizing, forgetting methods and formulas, complex calculations, and recalling prior knowledge were some reasons that were caused they could not understand the Engineering Mathematics concepts.

Students ranked the methods that can help them in the learning of Engineering Mathematics as the following:

Table 2. Ranking methods from students' approach

Method	Average ranking
Simplified concept	4.40
Teaching at students' level (peer teaching)	4.87
Individual homework and assignment	5.16
Classroom discussion with the peers and lecturer	5.25
Lecturer encouragement	5.79
Choosing problem related to the real world or students' major	6.39
Choosing relevant topics	6.59
Quiz/ test/ assessment or exam	6.80
Group project	7.58
Group work (collaboration) in the class	7.66
Peer and lecturer online / offline supports in the outside of class (Chat/ email/ online bulletin board …)	9.62
Using computer facilities (software / calculator …)	10.08
Using online facilities (website/ web learning modules/ online self assessment/ library…)	11.21

According to above table (Table 2), simplified concept and peer teaching (teaching at students level) are the highest important methods and using computer facilities (offline & online) are the lowest important methods to help students' learning in Engineering Mathematics from students' approaches. Furthermore, some methods such as online and offline communication, group work, grouping project, and even classroom discussion do not have high rank from students' views.

Many students suggested that more and different examples, exercises, assignments, and tutorials can help to improving students' difficulties in the understanding of Engineering Mathematics expected above-noted methods. Some of them mentioned about supporting their learning by solving some questions that are the same with the final exam questions. This indicates that students' behavior is on routine learning and thinking for passing final exam and no deep learning of topics that may be can help them in their fields. It is interesting that many students believed that the imaging and sketching are their greatest difficulties in the learning of Engineering Mathematics; however, just few of them mentioned that online and offline computer facilities can help them to overcome these difficulties. The rest of students also did not suggest any alternative methods to support imaging and sketching in 3-dimensions. On the other hand, based on the Table 2 the using of offline and online computer facilities as the most important ways of supporting visual thinking had the lowest ranking among the all methods from students' approaches.

4.2. Lecturer's Questionnaires Results

According to the collected data based on lecturers' questionnaires most lecturers also believed that the visualization in 3-dimenssion is the biggest difficulties that the students are encountered in Engineering Mathematics. Half of the lecturers believed that the lack of the basic

skills and knowledge (background) are other students' obstacles in Engineering Mathematics. In addition, some of them noted other students' obstacles such as students' difficulties to relate the subject and its applications and also memorizing and not understanding of concepts.

Lecturers ranked the methods that can help students in the learning of Engineering Mathematics as the following:

Table 3. Ranking methods from lecturers' approach

Method	Average ranking
Simplified concept	2.1
Teaching at students' level (peer teaching)	4.1
Choosing relevant topics	4.7
Lecture encouragement	5.8
Individual homework and assignment	6.1
Group work (collaboration) in the class	6.5
Classroom discussion with the peers and lecturer	6.5
Choosing problem related to the real world or students' major	6.7
Group project	7.7
Quiz/ test/ assessment or exam	7.8
Peer and lecturer online/ offline supports in the outside of class (Chat/ email/ online bulletin board …)	8.8
Using computer facilities (software / simulations/ calculator …)	9.3
Using online facilities (website/ web learning modules/ online self assessment/ library…)	10.6

According to above table (Table 3), simplified concept and peer teaching (teaching at students level) are the highest important methods and using computer facilities (offline & online) are the lowest important methods to help students' learning in Engineering Mathematics from lecturers' approaches. Similarity of the students' views, online and offline communication, group work, grouping project, and even classroom discussion do not have high rank to support students' obstacles from lecturers' views.

Majority of lecturers suggested that using computer facilities is the best way to overcome students' obstacle in visualization. However, it is interesting that using computer facilities (offline & online) as a way to support students' visualization has the lowest rank among all methods to support students abilities from the lecturers approach. Some lecturers suggested that doing more explanation and solving more exercise and examples especially from engineering approach can help students to overcome their difficulties.

5. Conclusion

According to the collected data from students' questionnaires, imaging and sketching in 3-dimensions are the greatest students' obstacles in Engineering Mathematics from students' approaches. Our data from lecturers' questionnaires support this finding and they also believed visualization is the greatest difficulties facing students in Engineering Mathematics. It seems Roselainy and her colleagues' method still cannot enough support students' imaging and sketching in Engineering Mathematics. Most lecturers suggested the computer facilities (offline & online) as a way for supporting visualization. However, due to the Table 2 and 3, both students and lecturers ranked the computer facilities (offline & online) as the lowest important methods to support their learning by visual thinking.

Many students noted that they cannot understand Engineering Mathematics cause of the following reasons: too much concepts/ facts/ theorems/ formulas, memorizing, forgetting methods and formulas, complex calculations, and recalling prior knowledge. Based on the lecturers' opinions, most of them believed the lack of the basic skills and knowledge (background) and memorizing of concept are other students' obstacles in the learning of Engineering Mathematics. It seems that the elements of active learning cannot enough support students to improve these difficulties. Especially in this method, we cannot see any strategies to support recalling prior knowledge revision. Moreover, some students believed that the examples with the solutions in the text book can help them for better understanding. This may aroused from the quite entrenching of students in their learning behavior and styles based on their previous mathematics learning. However, some lecturers believed that do a lot of exercise is a relevant way that can help students to learn better.

By comparing between Table 2 and 3, we can see the highest important methods, simplified concept and peer teaching (teaching at students level), and the lowest important methods, using computer facilities (offline & online), for overcoming Engineering Mathematics difficulties are the same ranking from students and lecturers approaches. Unfortunately, the analysis showed that for both groups of students and lecturers different thinking skills and tools from CPS such as communication, team work, and visualization are the lowest important methods for helping them in the learning of Engineering Mathematics. These results confirmed the needs and the importance of some reforms in engineering education not only in the learning and teaching of some subjects like mathematics that may be are seen as no priority subjects from students' view but also in supporting engineering students' generic skills such as communication and team work.

References

1. Croft, A. & Ward, J. A. (2001). Modern and Interactive Approach to Learning Engineering Mathematics, *British Journal of Educational Technology,* vol.32, no.2, pp 195-207.

2. Gray, E., Pinto, M., Pitta, D. & Tall, D. O. (1999). Knowledge Construction and Diverging Thinking in Elementary and Advanced Mathematics, *Educational Studies in Mathematics,* 38 (1-3), 111-113.

3. Herrmann, N. (1988). *The Creative Brain*, Brain Books, Lake Lure, North California.
4. Herrmann, N. (2001). Measurement of Brain Dominance. Online at: Available: www.herrmann.com.au/pdfs/articles/MeasurementofBrainDominance.pdf.
5. Isaksen, S. G., Dorval, K. B. & Treffinger, D. J. (1994). Creative approaches to problem solving. Dubuque, IA: Kendall-Hunt.
6. Isaksen, S. & Treffinger, D. J. (1985). *Creative Problem Solving: The Basic course*. Buffalo, NY: Bearly Limited.
7. León de la Barra, G. E., León de la Barra, M. B. & Urbina, A. M. (1997). "CPSWorkshops for Engineering Students", *Proceedings of Frontier in Education Conference* , Pittsburgh.
8. Lumsdaine, M. & Lumsdaine, E. (1995). CPS Thinking Skills for A Changing World ;Edward;McGraw-Hill.
9. Lumsdaine, E. & Voitle, J. (1993a). "Contextual Problem Solving in Heat Transfer and Fluid Mechanics," *AlChE Symposium Series, Heat Transfer-Atlanta* 1993, Volume 89, pp. 840-548.
10. Lumsdaine, E. & Voitle, J. (1993b). "Introducing Creativity and Design into Traditional Engineering Analysis Courses," *Proceedings, ASEE Annuul Conference,* Urbana, Illinois , pp. 843-847.
11. Mason, J., Burton, L. & Stacey, K. (1982). *Thinking Mathematically*. Addison-Wesley Publishing Company, Inc, Wokingham, England.
12. Osborn, A. F. (1953). Applied imagination: Principles and procedures of creative thinking. New York: Charles Scribner's Sons.
13. Osborn, A. F. (1963). *Applied Imagination: Principles and Procedures of Creative Thinking* (3rd ed.). New York: Charles Scribner's Sons.
14. Parnes, S. J. (1967). *Creative Behavior Guidebook.* New York: Scribners.
15. Roselainy Abd. Rahman, Sabariah Baharun & Yudariah Mohammad Yusof. (2007). Enhancing Thinking through Active Learning in Engineering Mathematics. In CD *Proceedings of Fourth Regional Conf. on Engineering Educ.*, Johor Bahru, 3–5 Dec.
16. Sabariah Baharun, Yudariah Mohd Yusof & Roselainy Abdul Rahman. (2008). *Facilitating Thinking and Communication in Mathematics*. Paper presented at ICME11th, Mexico, 6 – 13 July.
17. Schwarzenberger, R. L. E. (1980). 'Why calculus cannot be made easy', *Mathematical Gazette,* 64, 158–166.
18. Tall, D. O. (1985). Understanding the calculus, *Mathematics Teaching,* 110, 49-53.
19. Tall, D. O. (1988). Inconsistencies in the Learning of Calculus and Analysis, , *The Role of Inconsistent Ideas in Learning Mathematics*, AERA, New Orleans April 7 1989, published by Department of Math Ed, Georgia, 37-46.
20. Tall, D. O. (1992). Current difficulties in the teaching of mathematical analysis at university: an essay review of Victor Bryant Yet another introduction to analysis, *Zentralblatt für Didaktik der Mathematik*, 92/2, 37-42.
21. Tall, D. O. (1993). Students' obstacles in Calculus, Plenary Address, *Proceedings of Working Group 3 on Students' obstacles in Calculus*, ICME-7, Québec, Canada, 13-28.
22. Tall, D. O. (1995). Mathematical Growth in Elementary and Advanced Mathematical Thinking, plenary address. In L. Meira & D. Carraher, (Eds.), Proceedings of PME 19, Recife, Brazil, I, 61-75.
23. Tall, D. O. & Schwarzenberger, R. L. E. (1978). Conflicts in the learning of real numbers and limits, *Mathematics Teaching*, 82, 44-49.
24. Watson, A. & Mason, J. (1998). Questions and Prompts for Mathematical Thinking. AMT, Derby.
25. Yudariah Mohammad Yusof & Roselainy Abd. Rahman. (2004). *Teaching Engineering Students to Think Mathematically*. Paper presented at the Conference on Engineering Education, Kuala Lumpur, 14-15 December.
26. Yudariah Mohammad Yusof, Sabariah Baharun & Roselainy Abdul Rahman. (2009). *Multivariable Calculus for Independent Learners,* Pearson Malaysia Sdn. Bhd.